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Study of the Resistive Plate Chambers for the ALICE Dimuon Arm

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Abstract

The trigger system for the ALICE Dimuon Arm will be based on Resistive Plate Chambers. A RPC prototype, with electrodes made of low resistivity bakelite ($\rho \sim 3 \cdot 10^9 \Omega \text{cm}$) has been tested both at the SPS and at the GIF. The results for operation in streamer mode are presented here.

Key words: Resistive Plate Chambers, streamer, resistivity

1 Introduction

ALICE, the dedicated heavy-ion experiment at the LHC, will be equipped with a forward Dimuon Spectrometer (1) to investigate the production of heavy quarkonia (J/Ψ and Y), that will be detected through their decay in

the $\mu^+\mu^-$ channel. The transverse momentum of these muons is expected to be higher than the one of background muons, mainly coming from the decay of pions and kaons. Therefore, to select the events of interest, a cut on the transverse momentum of the tracks is performed by the trigger system, based on single-gap RPCs with x and y readout strips. The RPCs will be arranged in two stations, 1 meter apart, and will cover a total area of 150 m².

2 Requirements for the Dimuon Arm RPCs

The required rate capability is rather modest, since the RPCs are respectively expected to be fired at rates of about 3 Hz/cm² and 40 Hz/cm² for operation in Pb-Pb (at luminosity $\mathcal{L} = 10^{27}\text{cm}^{-2}\text{s}^{-1}$) and in Ca-Ca ($\mathcal{L} = 10^{29}\text{cm}^{-2}\text{s}^{-1}$). The needed time resolution is of few ns, to get the RPC signal in a 20 ns wide gate (given by the LHC clock). A cluster size close to one is also desired to minimize the occupancy of the read-out strips and to preserve the selectivity of the trigger. These requirements do not exclude, a priori, the possibility of working in streamer mode, although some improvement is needed with respect to the typical rate capabilities reported in literature so far. For this reason, we embarked on an experimental study of prototypes operated both in avalanche and in streamer mode. The results obtained for the avalanche mode are rather similar to those reported by different authors in this conference, while the ones for the streamer mode are presented in this contribution.

3 R&D Results

To increase the rate capability of RPCs operated in streamer mode, two parameters have been optimized. The first one is the gas mixture: tests with cosmic rays(2) have shown that the gas mixture Ar(49%), i-C₄H₁₀(7%), C₂H₂F₄(40%) and SF₆(4%) is effective for minimizing the charge of the streamers. The second one is the resistivity of bakelite electrodes, since a small resistivity implies a shorter recovery time of the voltage applied to the gas gap. A 50×50 cm² RPC prototype with bakelite electrodes (treated with linseed oil) of resistivity $\rho \simeq 3 \times 10^9 \Omega\text{cm}$ has been built and exposed to a 120 GeV/c pion beam at the CERN SPS. The efficiency of this detector is plotted in fig. 1 as a function of the incident flux. As it can be seen, when the RPC is operated at H.V.=9400 V (i.e. about 500 V above the beginning of the plateau) the efficiency is better than 95% for incident fluxes up to 1 kHz/cm². To illustrate the dependence of the rate capability on the electrode resistivity, the efficiency of two other RPC prototypes of higher resistivities (also tested at the SPS) are shown in the same figure.

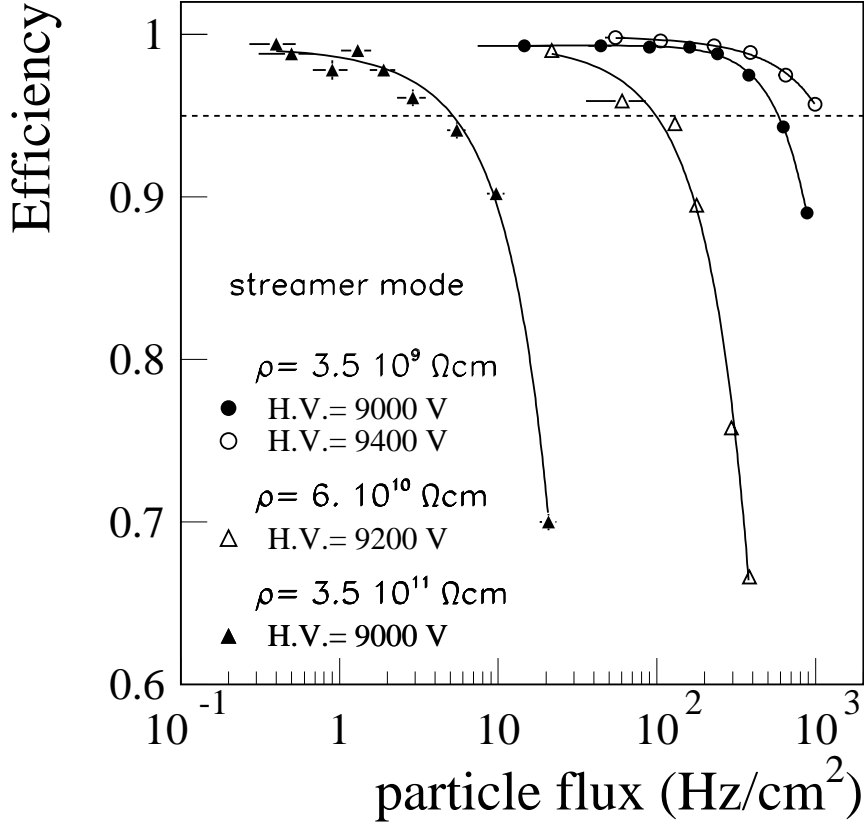


Fig. 1. Efficiency vs. incident flux for the low resistivity prototype (circles) and for other prototypes of higher resistivity.

The cluster size distributions for the low resistivity RPC prototype are shown in fig. 2 for an applied voltage of 9 kV. In fig. 2-(a) is visible the distribution obtained by equipping the RPC with 2 cm wide strips, while the distribution of fig. 2-(b) is for 1 cm wide strips. The mean cluster size and the fraction of events where the cluster size is larger than three are 1.1 (1.45) and 10^{-4} (10^{-3}) for 2 cm (1 cm) strips. The mean cluster size slightly increases with the high voltage; at 9.4 kV it is equal to 1.2 (1.7) for 2 cm (1cm) strips. We note that the cluster sizes of the low resistivity prototype are similar to the ones observed for the other prototypes of higher resistivity also studied at the SPS. This suggests that the dependence of the cluster size upon the bulk resistivity of the bakelite is weak.

The timing properties of the detector, which during this test was equipped with constant fraction discriminators, are summarized in fig. 3. The TDC

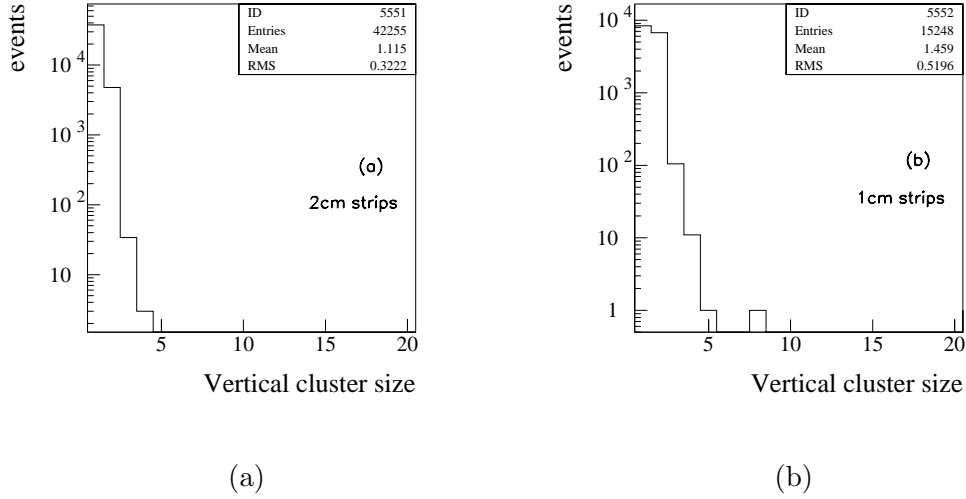


Fig. 2. Cluster size distributions for (a) 2 cm and (b) 1 cm wide read-out strips distributions at 9.4 kV are shown in fig. 3-(a) for incident fluxes of 100 and 650 Hz/cm². The distribution is nearly gaussian for the lower flux; when the flux increases a tail appears on the right side of the gaussian peak. Nevertheless, as shown in fig. 3-(b), more than 98% of the events are contained in a 20 ns wide window which, as previously mentioned, is a relevant point to operate the chambers in ALICE.

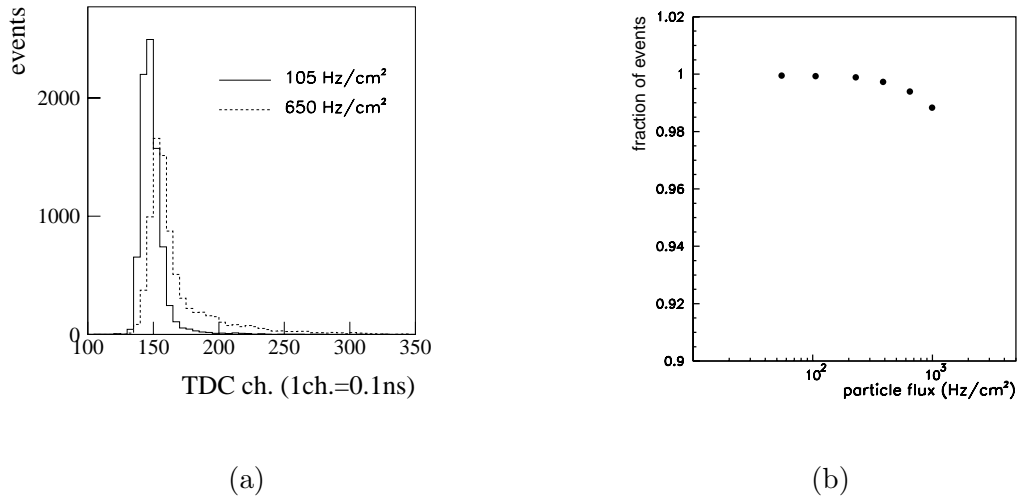


Fig. 3. (a) Time distributions for fluxes of 105 and 650 Hz/cm² at 9.4 kV and (b) fraction of events contained within a 20 ns time window.

The rate capability measured at the SPS (i.e. under local illumination, limited

in time by the burst duration of 2.5 s) might not be representative for continuous illumination of the whole detector. Therefore, after the SPS tests, the low resistivity prototype was tested at the CERN Gamma Irradiation Facility (GIF), where it was exposed to 660 keV γ -rays emitted by a ^{137}Cs source. The RPC counting rate was about 300 Hz/cm², constant over the detector surface. It is worth to remark that this rate is two orders of magnitude higher than the one expected in ALICE for Pb-Pb. This means that, from the point of view of the integrated rate, one day of data taking at the GIF corresponds to about 100 days of Pb-Pb data taking in ALICE. In presence of the photon flux, cosmic rays crossing the chamber were selected by a telescope made of four plastic scintillators. The RPC efficiency for cosmic rays was measured during about 20 subsequent runs, covering an overall period of three days. The results are shown in fig. 4 for a RPC H.V. of 9.4 kV. As it can be seen, the behaviour of the chamber is stable and its efficiency is about 90%. Actually, this value is only a lower limit, since a fraction of the triggers (about 5%) comes from random coincidences of the four scintillators due to their high single rate in the GIF environment.

To conclude this section, we explicitly note that the single rate of the low resistivity RPC prototype, when measured outside of the SPS or GIF experimental areas, is about 0.05-0.07 Hz/cm², i.e. a value that is very close to the ones observed for RPCs of considerably higher resistivity (3). On the other hand, the dark current is quite high, of the order of 30 μA . This value seems to be related to the relatively low resistivity of the vetronite frame used for this chamber. In fact, a new prototype made with bakelite of similar resistivity but with a polycarbonate frame (which has a much higher resistivity than vetronite) exhibits a dark current as small as 5 μA .

4 Conclusions

Tests carried out both at the SPS and at the GIF indicate that rate capabilities of the order of several hundreds Hz/cm² can be achieved by RPCs with electrode resistivity of the order of few times 10⁹ Ωcm operated in streamer mode. The cluster size and the single rate of the detector are similar to those observed for RPCs of higher resistivities. The time resolution is adequate to fulfil the ALICE trigger requirements, as it can be seen by the high fraction of events included in a 20 ns time gate.

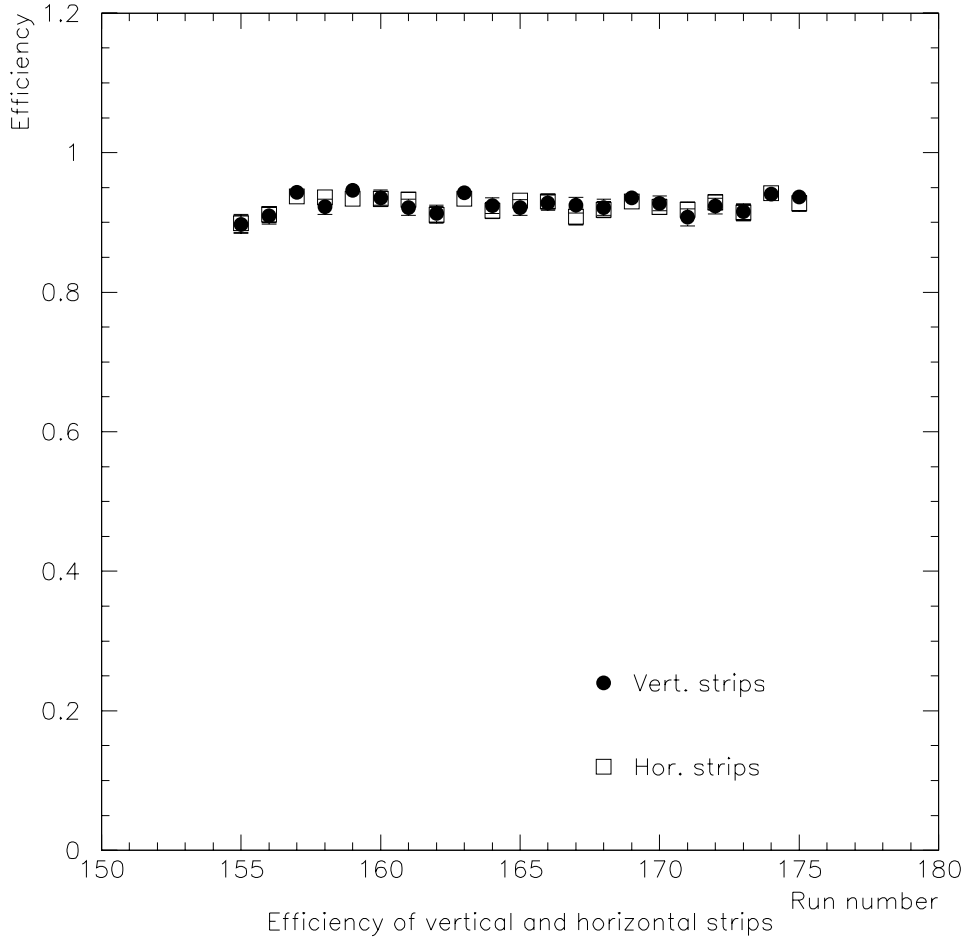


Fig. 4. Cosmic rays efficiency measured at the GIF for a uniform counting rate of about 300 Hz/cm^2 at 9.4 kV

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